SOLAR/1010-79/50

Solar Project Description

A-FRAME INDUSTRIES' SINGLE FAMILY RESIDENCE
Kaneohe, Hawaii
July 27, 1979

U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

NOTICE

SOLAR/1010-79/50
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SOLAR PROJECT DESCRIPTION
FOR
A-FRAME INDUSTRIES'
SINGLE FAMILY RESIDENCE - KANEOHE, HAWAII

Prepared for the
Department of Housing and Urban Development

Under Contract Number
H-2372

David Moore
Solar Heating and Cooling Demonstration Program Manager

By

The Boeing Company
David Beers
Program Manager

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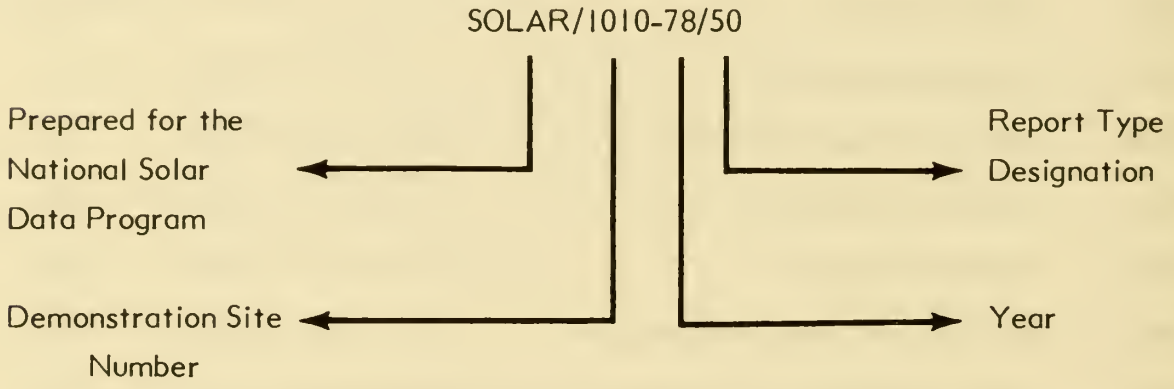
NATIONAL SOLAR DATA PROGRAM REPORTS

Reports prepared for the National Solar Data Program are numbered under a specific format. For example, this report for A-Frame Industries single family residence, HUD Grant No. H-2598, is designated as SOLAR/1010-78/50. The elements of this designation are explained in the following illustration:



Demonstration Site Number: Each project has its own discrete number - 1000 through 1999 for residential sites and 2000 through 2999 for commercial sites.

Report Type Designation:
This number identifies the type of report, e.g.,

- Monthly Performance Reports -- designated by the numbers 01 (for January) through 12 (for December);
- Solar Energy System Performance Evaluations -- designated by the number 14;
- Solar Project Descriptions -- designated by the number 50;
- Solar Project Cost Reports -- designated by the number 60.

These reports are disseminated through the U.S. Department of Energy, Technical Information Center, P.O. Box 62, Oak Ridge, Tennessee 37830.

I. FOREWORD

The National Program for Solar Heating and Cooling is being conducted by the Department of Energy (DOE) as mandated by the Solar Heating and Cooling Demonstration Act of 1974. The Department of Housing & Urban Development is responsible to DOE for the Solar Residential Demonstration Program. The overall goal of the Federal Demonstration Program is to assist in the establishment of a viable solar industry and to achieve a substantial reduction in fossil fuel use through widespread use of solar heating and cooling applications. An analysis and synthesis of the information gathered through this program will be disseminated in site-specific reports and summary documents as products of the National Solar Data Program. These reports will cover topics such as:

- o Solar Project Description.
- o Operational Experience.
- o System Performance Evaluation.
- o Monthly Performance Reports.

Information contained herein for this Solar Project Description report has been extracted from data collected during site visits and from reference documents such as the project proposal, designer specifications, grantee submittals, manufacturer literature, photographs, specific "as-built" data and other project documentation available. The remaining reports in this series will utilize the Solar Project Description for supporting reference.

II. EXECUTIVE SUMMARY

The following are the major solar energy descriptors:

- o Collector Type -- Liquid flat plate, tube and plate
- o Freeze Protection -- None required
- o Application -- Domestic hot water
- o Storage -- Preheated water
- o New/Retrofit -- New
- o Performance Evaluation Instrumentation -- Yes

The A-Frame Industries site located in Kaneohe, Hawaii and is a single family residence containing a solar energy system designed to provide domestic hot water heating. It is an open system, utilizing city water pressure to overcome the pressure head of the DHW tank and solar collector subsystem. The system uses city water as the common heat transfer medium, and contains no energy storage tank or DHW tank heat exchanger loop. Therefore, the total operating energy is in the energy collection and storage subsystem (ECSS).

The collector consists of an array of four flat plate collectors with a gross area of 76.6 square feet. The collectors face 10 degrees east of south at an angle of 21 degrees from the horizontal. The heat transfer medium is potable water, which is stored in a 120 gallon water heater storage tank and supplied, on demand, to the domestic hot water supply. Auxiliary heat is supplied by a 4 kilowatt electrical heating element. The collector loop pump is activated when the collector temperature exceeds the storage temperature by 5^{o} F. The pump is stopped when this temperature difference becomes less than 2^{o} F. The hot water service design temperature is 140^{o} F. No maximum temperature control or freeze protection is provided.

The solar energy system was designed by Miromit Ashkelon of Tel Aviv, Israel and installed by their distributon in Hawaii, Sunsource Pacific, Inc.

The house has been fully instrumented for performance evaluation of the solar system since February 1978 and the compiled data is integrated into the National Solar Data Network.

Original cost estimates for provisioning and installation of the solar system are given in Section VI of this report. The final solar system, however, cost and of its instrumentation are not included.

III. SITE AND BUILDING DESCRIPTION

Site Description

- Latitude - 21° N
- Longitude - 158°
- Elevation - 500 feet
- Annual degree days (65° F base)
  - Heating - 0
  - Data location - Kaneohe, Hawaii
  - Data reference - 1977 ASHRAE Handbook
- Average horizontal insolation
  - January - 1400 Btu/ft^2/day
  - July - 1675 Btu/ft^2/day
  - Data location - Kaneohe, Hawaii
  - Data reference - ASHRAE Fundamental Handbook
- Shading - None

Building Description

- Occupancy
  - Family of two
  - Three bedroom, living room, kitchen, laundry room, covered lanai, two bathrooms, detatched garage
- Solar system provides - Hot water preheating
- Height - One story
- Front side view - Due south
- Conditioned floor area - 1,232 ft^2
- Roof slope at collector - 13° pitch angle
- Special features - Northern end of house is on stilts

Structure

- Walls (Solar conditioned space)
  - Frame Wood framing on wood posts set in concrete
  - Exterior finish - Plywood
  - Insulation -
  - Interior finish - Gypsum wallboard
  - Windows -
    - Glazing - Single pane
    - Less than 20 percent of exterior wall area
  - Doors
    - Front door - Solid wood
    - Rear door - Solid wood
- Roof
  - Structural frame - Structural wood with 1 x 8 T&G cedar sheathing.
  - Exterior finish - Asphalt shingle
  - Interior finish - Living room & kitchen - open beam, all others 1 x 2 kiln dried wood

Mechanical System

- Domestic Hot Water
  - Daily water demand - 41.4 gallons per day
  - Solar - Open system pumping water through solar collectors into storage tank
  - Auxiliary - 120 gallon electric water heaters
    - Type - 4 kw electrical heating element
    - Manufacturer - American Appliance

IV. SOLAR SYSTEM DESCRIPTION

A. General Overview

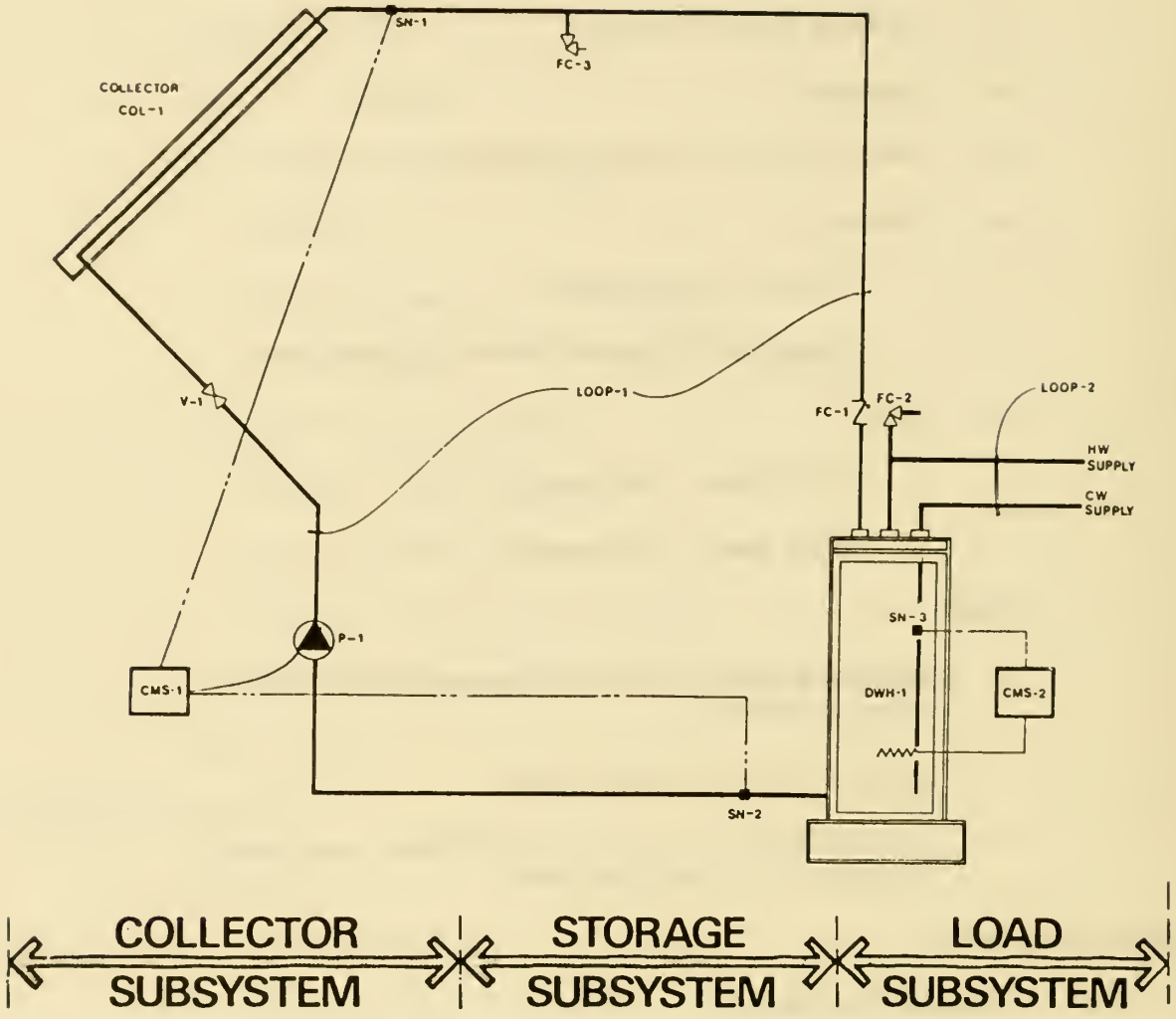


Figure IV-A-1. General Overview

The domestic hot water heating demonstration system used at the A-Frame Industries Grant·(Grant No. H-2598) is represented in Figure IV-A-1. The Energy Collection and Storage Subsystem (ECSS) is composed of the collector array, the primary storage medium, the transport loops between these, and other components in the system designed which are necessary to mechanize the collector and storage equipment. The system includes a four kilowatt electrical, strip type, immersion heating element in the 120 gallon storage tank as an auxiliary hot water supply system.

Subsequent sections describe the collector, storage, storage-to-load, and auxiliary energy subsystems. Specific details of the operating modes are described in the final section. Figure IV-A-1 is a system schematic diagram. Appendix A presents a glossary.

B. Collector Subsystem (See Figure IV-B-1)

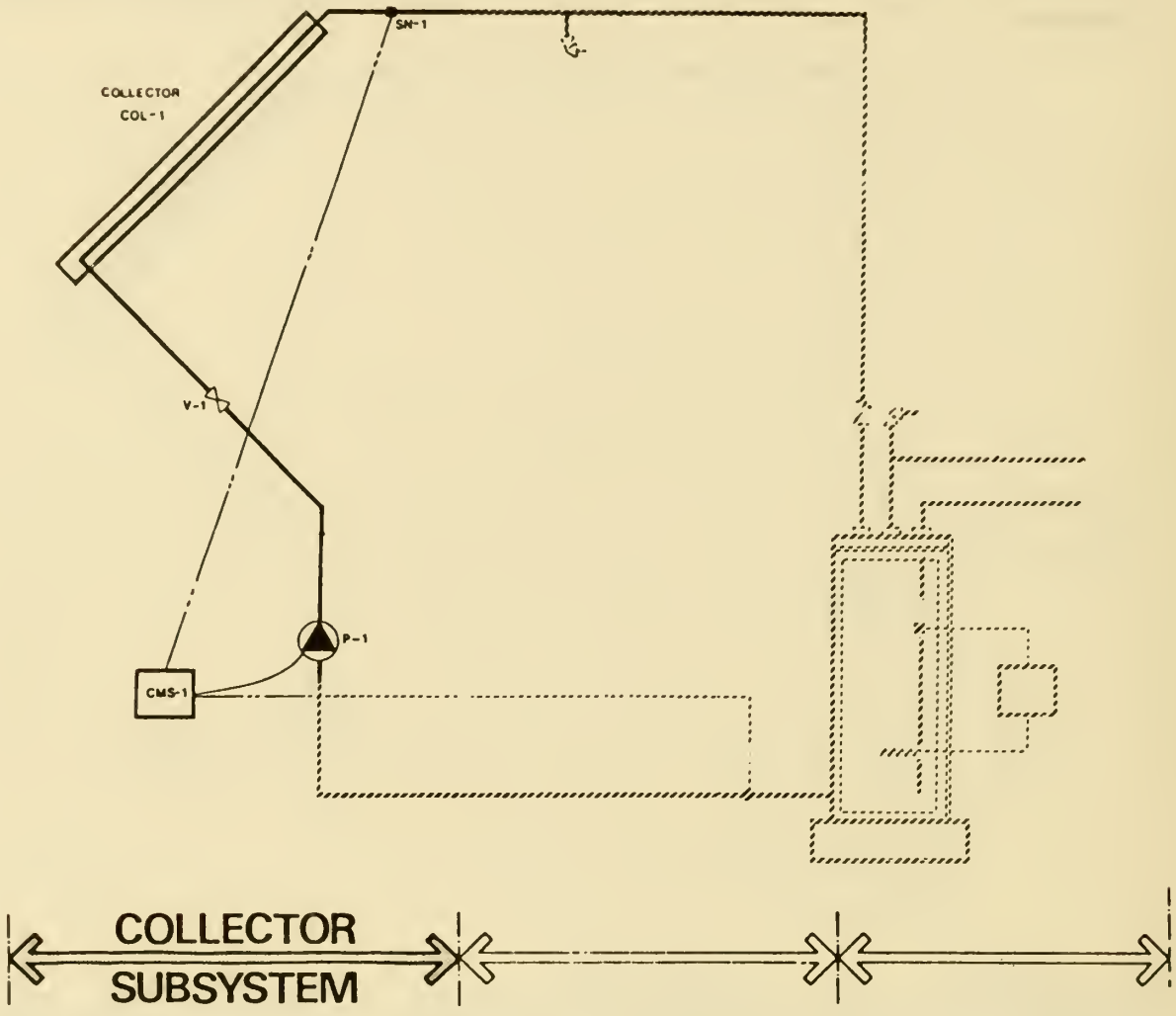


Figure IV-B-1. Collector Subsystem

General Description

The 76.6 ft^2 collector array is mounted at a 21° slope to the horizontal on a sloped portion of the sourtherly part of the roof. The collector strong back structure is secured by thru-bolting through the roof and roof rafting. The four collector panels, weighing 169 pounds per panel, empty were assembled at the site.

Collector (COL-1) (See Figure IV-B-2)

- Manufacturer - Miromit Ashkelon
- Model Name/Number - 299481-4
- Type - Liquid flat plate, tube and plate
- Location - Roof
- Orientation - 10° east of south
- Tilt angle - 21° from the horizontal
- Number of collector panels - 4
- Array configuration - Four panels side by side
- Collector enclosure
  - Total gross area of array - 72 square feet
  - Net aperture area - 68 square feet
  - Weight per panel, empty - 169 pounds
  - Weight per panel, full - 179 pounds
  - Weight of filled array and support structure - 900 pounds
  - Panel length - 73 inches
  - Panel width - 37.8 inches
  - Frame depth - 3.5 inches
  - Standoff height - 8 inch
- Cover plate
  - Number of cover plates - One
  - Manufacturer - ASG Industries
  - Product Name/Number - Sundex A
  - Material - Tempered glass, water white
  - Thickness - 0.156 inches
  - Coating - None

- Optical properties (solar region)
  - Transmittance 91%
  - Reflectance 8%
  - Emittance 1%
- Edge or surface treatment, other than coating - Mechanical ground
- Coating on cover plate material - None

- Absorber
  - Manufacturer - Miromit Ashkelon
  - Model Name/Number - 100
  - Material - Galvanized steel
  - Coating
    - Material - Tabor selective black
    - Application - Vacuum deposited
    - Absorptance, solar region - 92%
    - Reflectance, solar region - 8%
    - Emittance - 10%
- Heat transfer fluid passages
  - Location of fluid passages - Beneath absorber
  - Fluid passage materials - IPS galvanized steel
  - Fluid passage wall thickness - .094 inches
  - Fluid passage bond to substrate - Mechanical rolled bond
  - Protective costing inside fluid passage - Galvanized
- Insulation
  - Layer one and layer two, sides
    - Manufacturer - Celotex
    - Material - Celotex board
    - Thermal resistance - R-3

- Layer one - back
  - Material - Mineral wool
  - Thermal resistance - R-13

- Gaskets and sealants
  - Inner cover - GE 1200 silicone sealant
  - Frame joint - Welded
  - Backing plate - Mechanical crimp

- Frame
  - Manufacturer - Miromit Ashkelon
  - Product Name/Number - Miromit 100 24 gage galvanized steel
  - Material - 24 gage galvanized steel
  - Protective coating - Galvanized and painted
  - Number of structure attach points per module to building - 4

- Collector performance
  - Method of evaluation - ASHRAE $(t_i-t_a)/I_t$
  - y intercept - .73° F hr ft^2/Btu
  - Slope - 0.92
  - Test flow rate - 15.0 pounds per hour

Liquid Circulation Loop No. 1 (COL-1 to DHW-1)

- Design maximum operating temperature - 140° F
- Heating design liquid flow
  - Maximum - 0.8 gal/min
- Heat transfer medium
  - Material - Water 100% of total volume
  - Specific heat - 1.00 Btu/lb °F
  - Density - 63 lb/ft^3

Figure IV-B-2. Solar Collector

- Heat capacity - 62.4 Btu/ft^3 ^oF
- Boiling point - 212^o F
- Freezing point - 32^o F
- Maximum recommended use temperature - 160^o F
- Toxicity - Potable
- Chemical feeder to maintain pH factor - None
- Inhibitor - No

- Piping
  - Location - Above grade
  - Exterior finish - SPANDEX, self vulcanized
  - Insulation - Celular rubber
  - Rigid - Copper type L, hard 1/2 inch tube, soldered
  - Joint finish - Tape and mastic
- Circulator Pump (P-1)
  - Manufacturer - Grundfos
  - Model Name/Number - UP 25-42SE
  - Type - Centrifugal
  - Maximum operating conditions
    - Static pressure - 150 psi
    - Dynamic pressure - 6.1 psi
    - Temperature - 210^o F
  - Material exposed to heat transfer fluid - Stainless steel 316
  - Motor size - 0.05 hp, 115 volts, 1 phase, 60 Hz
  - Maximum motor speed - 1725 rpm
  - Drive - Direct
  - Speed - Single

- Circulating volume - Low head mode, 23.0 gal/min
- Operating head (dynamic) - Low head mode, 6.06 psi

- Distribution Valve (V-1)
  - Manufacturer - Bell and Gossett
  - Model Name/Number - Bivco No. 150, 1/2 inch bronze, circuit setter balance
  - Function - Flow adjusting
  - Operation - Manual
  - Type - Plug
  - Material exposed to heat transfer fluid - Bronze
  - Maximum rated operating conditions
    - Pressure - 125 psi
    - Temperature - 250° F

Control Mode Selector (CMS-1)

- Manufacturer - Hawthorne Industries
- Model Name/Number - Fixflow 1503
- Modes controlled
  - Collector to storage
    - OFF when SN-01 is less than 4° F above SN-02
- Sensors (SN-1) and (SN-2)
  - Manufacturer - Hawthorne
  - Type - Thermostatic
- Flow Control (FC-1)
  - Manufacturer - Bivco Valve
  - Product Name/Number - Lift Multi-valve
  - Type - Check valve

- Flow Control (FC-3)
  - Manufacturer - Watts
  - Product Name/Number - No. 174A
  - Type - Pressure relief valve

C. Storage Subsystem (See Figure IV-C-1)

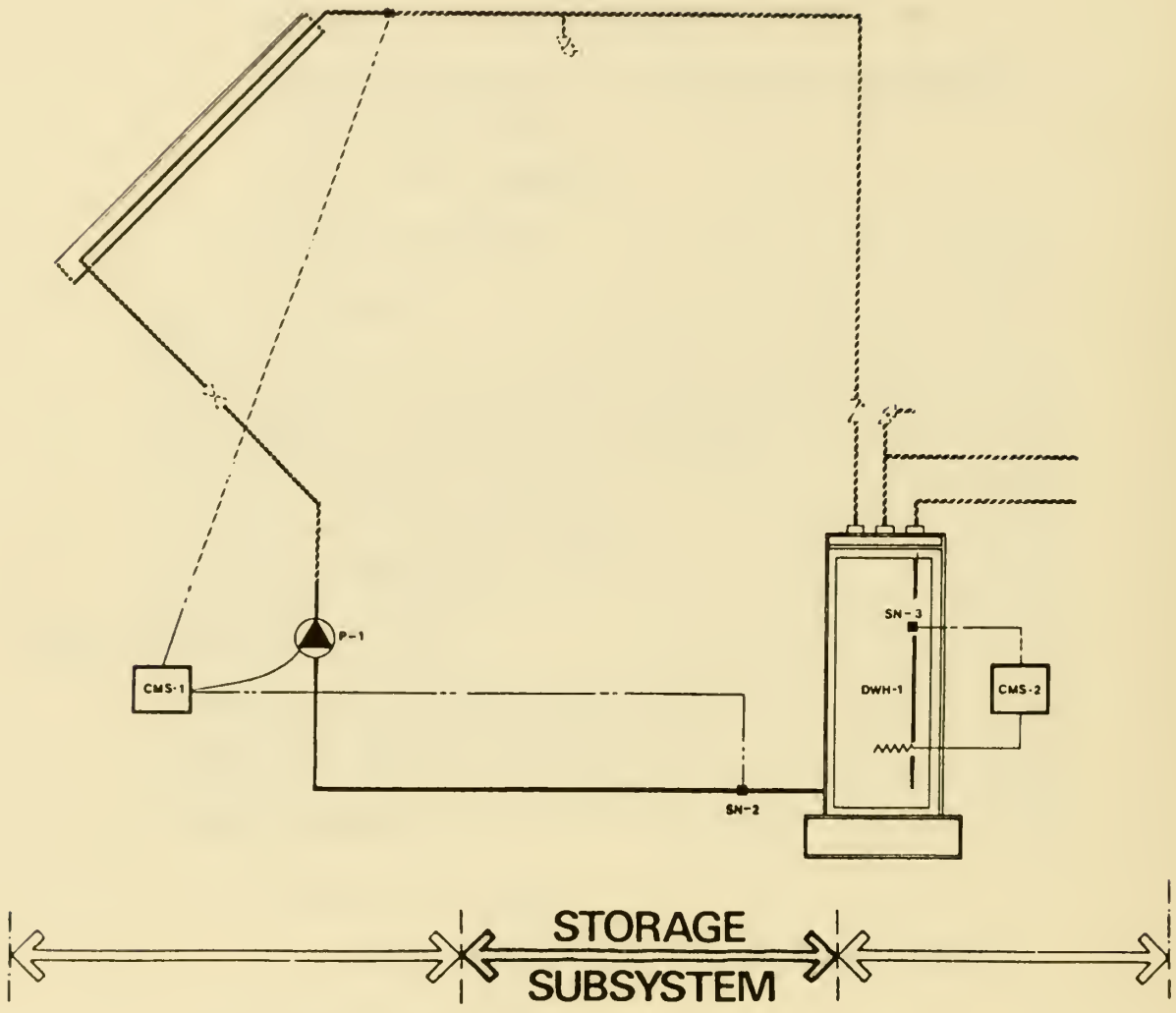


Figure IV-C-1. Storage Subsystem

The storage tank is the domestic water heater (DHW-1) tank.

Thermal Storage Unit (DHW-1)

- Domestic water heater (DHW-1)
  - Manufacturer - American Appliance

- Model Name/Number - AMG120
- Total storage volume - 120 gallons
- Auxiliary energy - Electricity
- Manufacturers rating
  - Tank volume - 120 gallons
  - Energy input - 15360 Btu/hr
  - Energy output - 15000 Btu/hr
  - Maximum pressure - 300 psi
  - Maximum temperataure - 170° F
  - Design operating pressure - 150 psi
  - Maximum recovery rate - 18 gal/hr

- Storage medium
  - Material - 100% water
  - Input temperature - 74° F (yearly average)
  - Output temperature (design) - 140° F
- Storage construction
  - External surface area - 250 sq. ft.
  - Thermal resistance insulation - R-1.6
  - Corrosion protection - Magnesium Anode
  - Heating stages - One
- Flow Control (FC-2)
  - Manufacturer - Watts
  - Product Name/Number - 100XL
  - Type - Pressure/Temperature relief valve

D. Energy To Load Subsystem (See Figure IV-D-1)

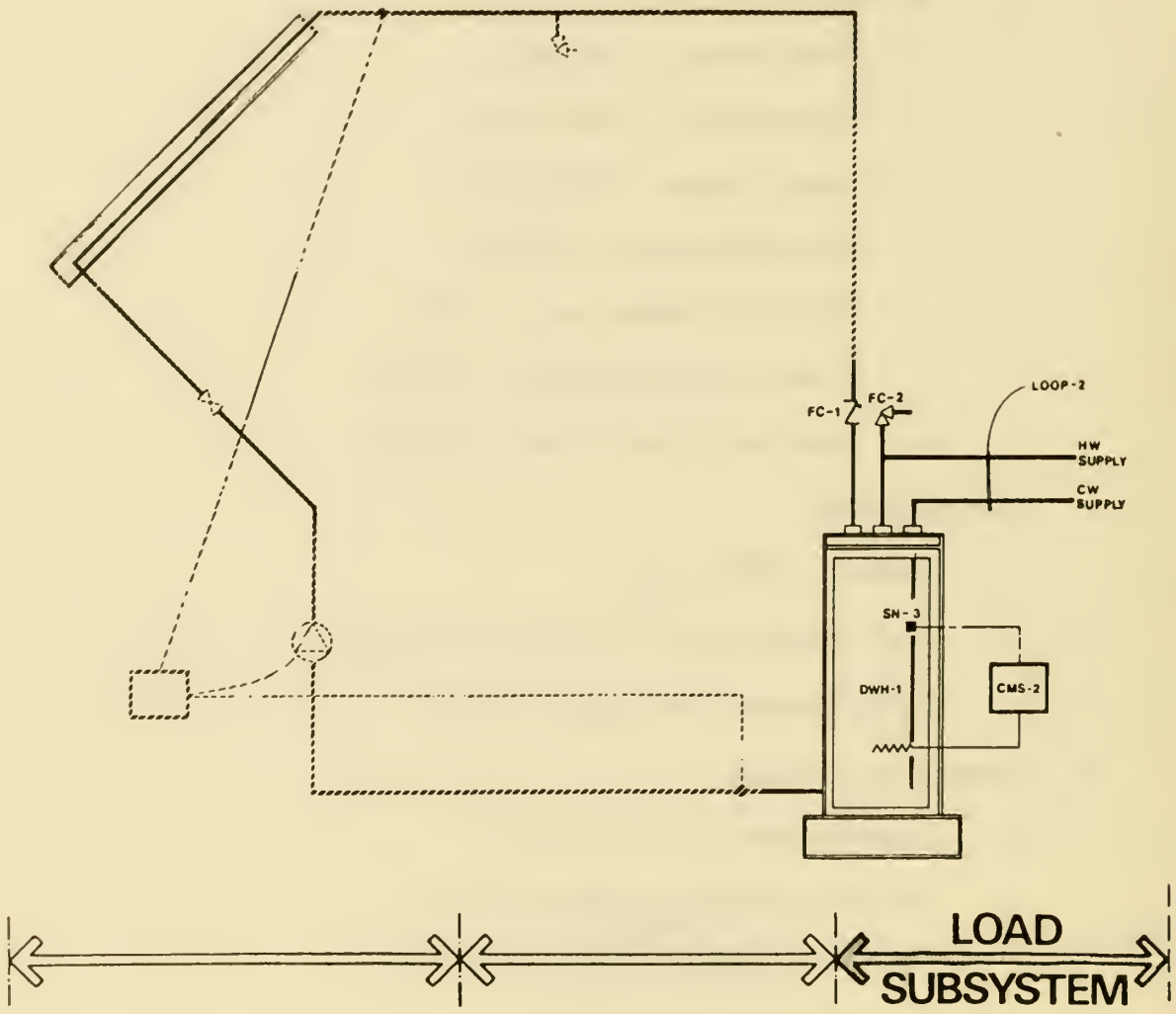


Figure IV-D-1. Energy-to-Load System

The 31 individual DHW units are supplied with preheated water from a single circulating loop. This loop is designed to take advantage of the building elevations so that when water is drawn from any unit, an undirectional flow is established which will continue to circulate till demand ceases. Preheated water is thus drawn from storage and is available in the circulation loop.

Liquid Circulation Loop No. 2 (DHW-1 to hot water supply)

- Maximum design operating temperature - 160° F
- Provision for expansion - Open system
- Heat transfer medium
  - Medium - 100% water
  - Specific heat - 1.00 Btu/lb °F
  - Boiling point - 212° F
  - Freezing point - 32° F
  - Maximum recommended use temperature - 210° F
  - Toxicity - Potable
  - pH factor - 7.0
  - Piping
    - Rigid - Hard copper, type K
    - Location - Above grade

E. Auxiliary Subsystems (See Figure IV-E-1)

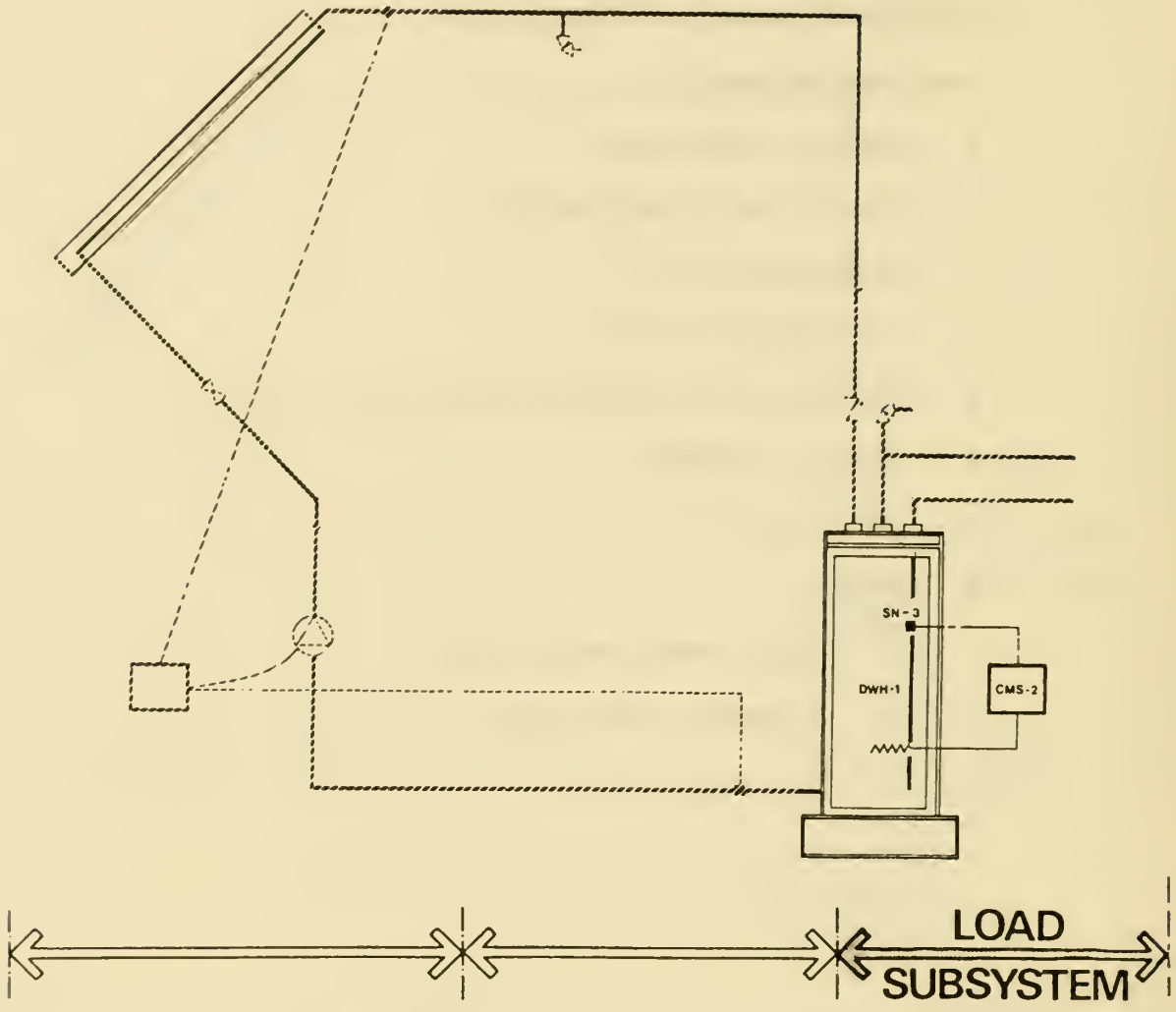


Figure IV-E-1. Auxiliary-to-Load Subsystem

Domestic Water Heater (DHW-1)

- Domestic water heater (DHW-1)
  - Manufacturer - American Appliance
  - Model Name/Number - AMG120
  - Total storage volume - 120 gallons
  - Auxiliary energy - Electricity

- Manufacturers rating
  - Tank volume - 120 gallons
  - Energy input - 15360 Btu/hr
  - Energy output - 15000 Btu/hr
  - Maximum pressure - 300 psi
  - Maximum temperataure - 170° F
  - Design operating pressure - 150 psi
  - Maximum recovery rate - 18 gal/hr
- Storage medium
  - Material - 100% water
  - Input temperature - 74° F (yearly average)
  - Output temperature (design) - 140° F
- Storage construction
  - External surface area - 250 sq. ft.
  - Thermal resistance insulation - R-16
  - Corrosion protection - Magnesium Anode
  - Heating stages - One
  - Interior lining - Glass
  - Insulation - Fiberglass
  - Location - Garage
  - Toxicity - Potable

F. Modes of Operation (See Figure (V-F-1)

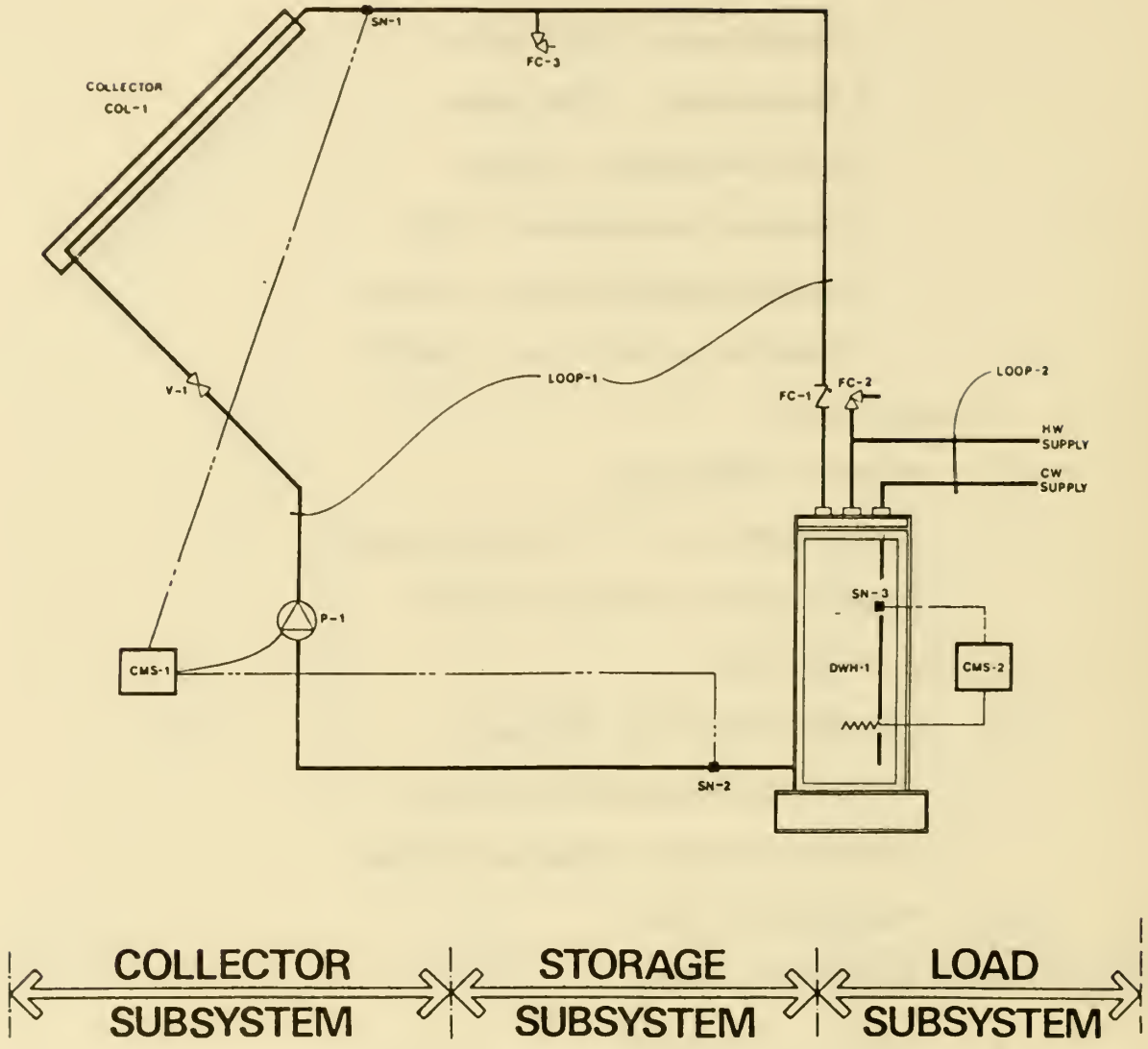


Figure IV-F-1. Controls Diagram

The A-Frame Industries' "Solar Home" is designed to utilize an open solar hot water heating system, see figure IV-F-1. The home is built with a North-South orientation providing an optimum Southern exposure for its four Miromit Ashkelon heat collecting panels. The four panels are used in conjunction with a 120 gallon heater/storage combination tank. It is insulated with 3 inches of urethane foam and surrounded by a steel jacket. The heating element controls are protected by the urethane. The lower element in the heater has been disconnected, allowing only the upper element to operate.

The system itself is simple. It has a sensor located in the upper portion of the collector and one located at the bottom of the storage tank. The upper sensor is at the hottest part of the system and the lower sensor at the coldest. When the upper sensor senses five degrees higher temperature than the lower sensor, the master control box automatically activates the pump. The pump circulates the water past the circuit setting balance valve which restricts the flow to get maximum efficiency and temperature rise. The water passes through to the bottom portion of the collectors, rises through and out the top. Then it returns down the pipe, past a check valve and brought approximately half way into the storage tank, about two inches below the heating element. If the water coming off the collector into the storage is hotter than what the thermostatic setting is for the element, it will rise above the element and maintain the heat there. If it is colder than that temperature, it will fall to the bottom of the tank for recirculation. The system will circulate the water in the tank approximately 1-1/2 times per day. This permits maximum temperatures in storage for the amount of collector area used. The system automatically turns off when there is less than two degrees temperature differential.

System Operation Modes

Mode 1 - Collector to storage

The circulating heat transfer medium (water) is pumped through the collector maintaining water temperature in the storage at an average of 131° F. The collector loop pump is automatically activated when the collector temperature exceeds the storage temperature by 5° F.

Mode 2 - Auxiliary Domestic Hot Water Heating

If for any reason sufficient supply of hot water is not available through the collector, the auxiliary heating system, consisting of an electric heating element controlled by a temperature sensor, will be automatically activated. The controlling sensor turns on the heating element whenever the water temperature in the heater/storage tank drops below 120° F.

V. PERFORMANCE EVALUATION INSTRUMENTATION

A. The National Solar Data Network

The National Solar Data Network (see figure V-A-1) has been developed for the Department of Energy to process data collected from specific residential demonstration sites which were selected for thermal performance evaluation. The data flow in the Network includes monthly and seasonal system performance reports describing the thermal performance of the solar energy system and subsystems.

The performance evaluation instrumentation at each selected demonstration site is part of a comprehensive data collection system that allows for valid analyses of the solar system performance. Collected data are both applicable and practical in calculating thermal performance factors that describe the behavior of the solar system (see NBSIR 76-1137), National Bureau of Standards. Additional instrumentation may also be included as a result of site-specific requirements. Typically, the instrumentation includes sensors that monitor the following:

- Total insolation in the plane of the collector array
- Ambient temperature
- Collector subsystem flow rate and temperatures
- Storage inlet flow rate and temperatures
- Storage outlet flow rate and temperatures
- Storage temperature
- Storage-to-load subsystem flow rate and temperatures
- Auxiliary fuel flow rates

Site data are recorded sutomatically at prescribed intervals by the Site Data Acquisition System (SDAS). The recorded data are transmitted daily to the Communications Processor in the Central Data Processing System (CDPS). The communications link between every SDAS and the CDPS consists of voice-grade telephone lines and telephone data couplers. A reading is transmitted from the SDAS internal timer with every data sample to ensure that the data are time-tagged correctly.

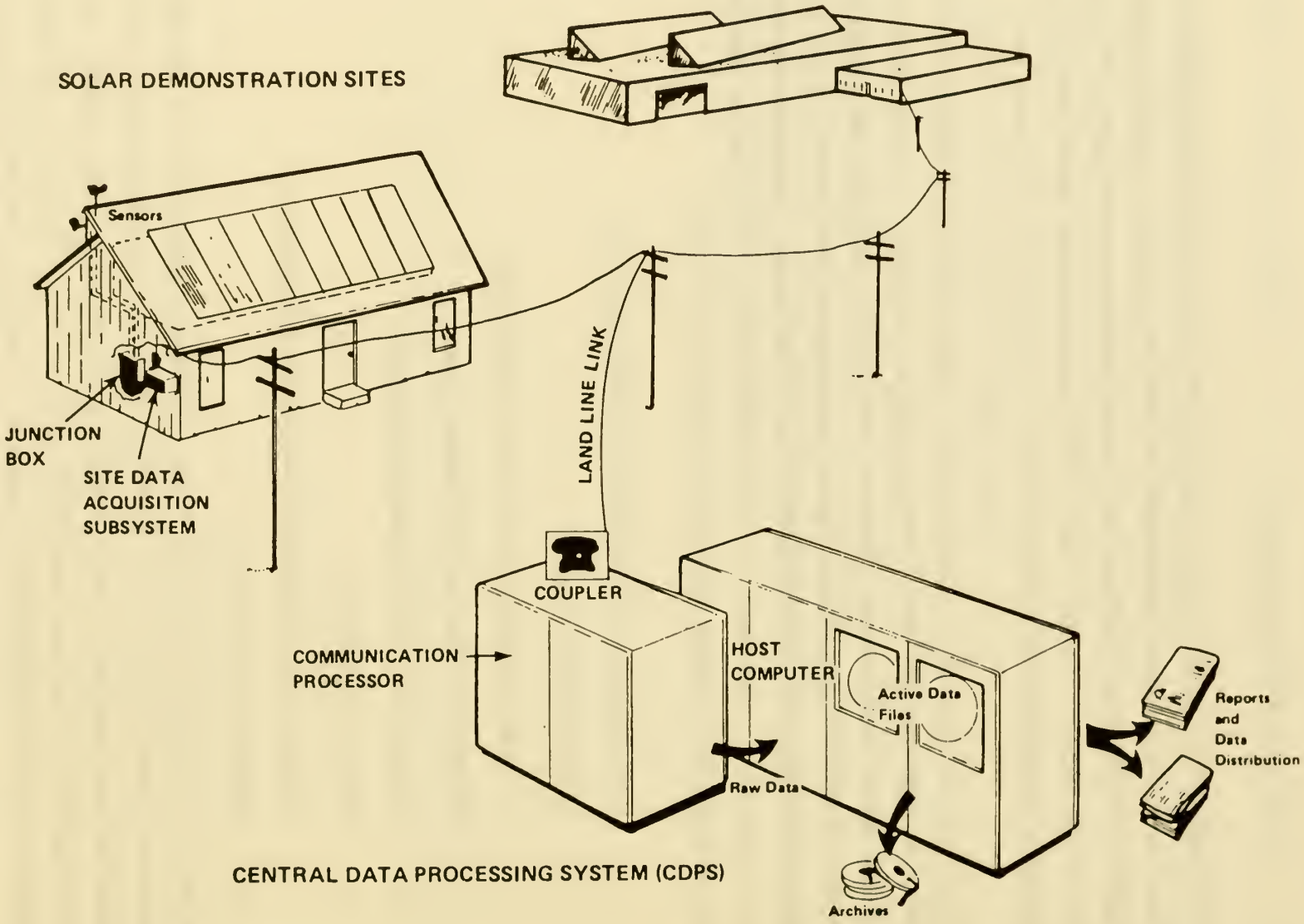


Figure V-A-1. The National Solar Data Network

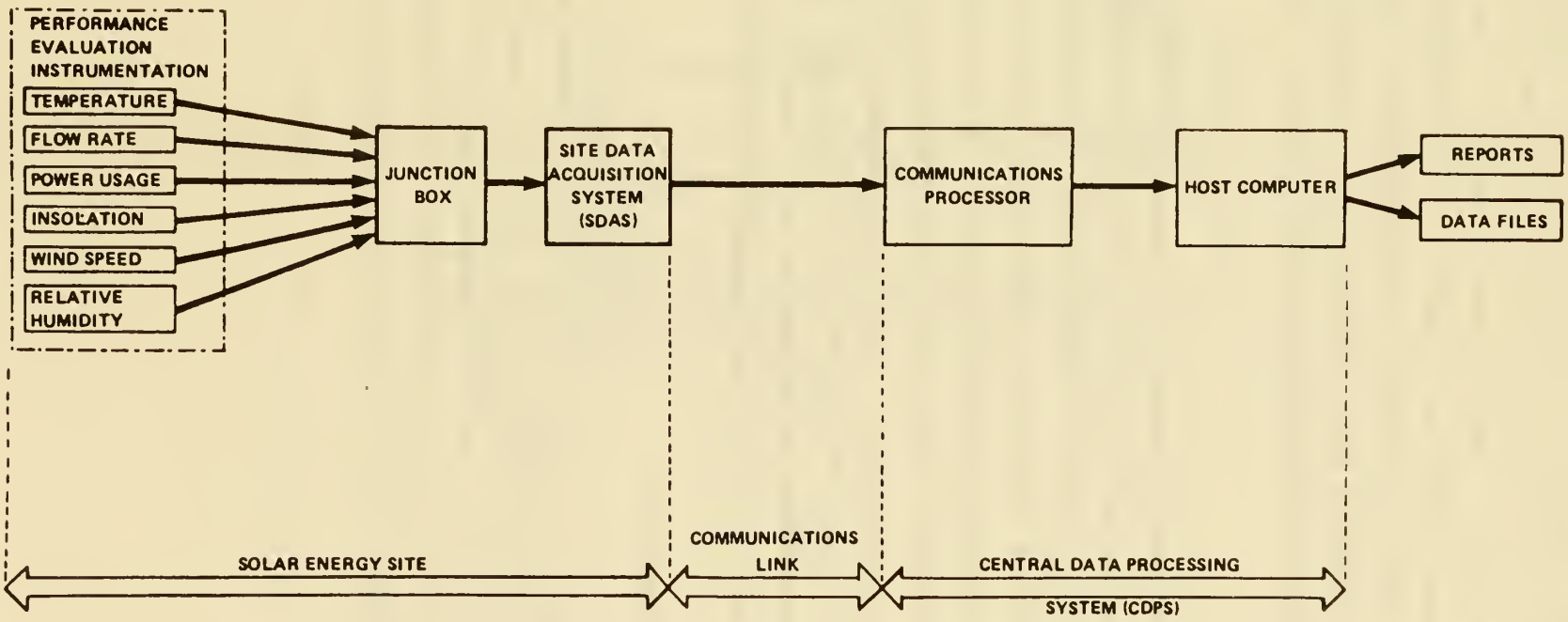


Figure V-A-2. Data Flow Path for the National Solar Data Network

The Communications Processor scans the receiving data to identify any apparent transmission errors and verifies correct site contact by checking the address code transmitted by the SDAS. Data is stored temporarily in the Communications Processor and processed by the Host Computer. The processing includes measurement checking to ensure that the data are reasonable; that is, that they are not beyond the known instrument limits and that they are not erratic. Data which appear questionable are discarded and are not used in the solar system preformance analyses.

Appropriate equations were formulated and programmed to define desired performance factors for the solar energy systems at each selected demonstration site. A performance factor is a number that describes either the efficiency or the quantity of energy lost, gained, or converted by a solar energy system or by a component. All vaid data are processed using these performance factor equations to generate hourly performance factors. Hourly performance factors are integrated into daily and monthly performance factors. These hourly, daily, and monthly performance factors are stored in data files in the CDPS. These data files also include measurement data, expressed in engineering units; numerical and textual site identification; and specific site data used in generating the performance factors.

B. On-Site Instrumentation

The on-site instrumentation includes sensors to monitor the various parameters of the solar energy system, a junction box, and a Site Data Acquisition System that stores and transmits data to the Host Computer (see figure V-A-1 and V-A-2). Specific information for temperature, flow, power and miscellaneous sensors are presented in tabular form. Sensor locations are shown in figure V-B-1.

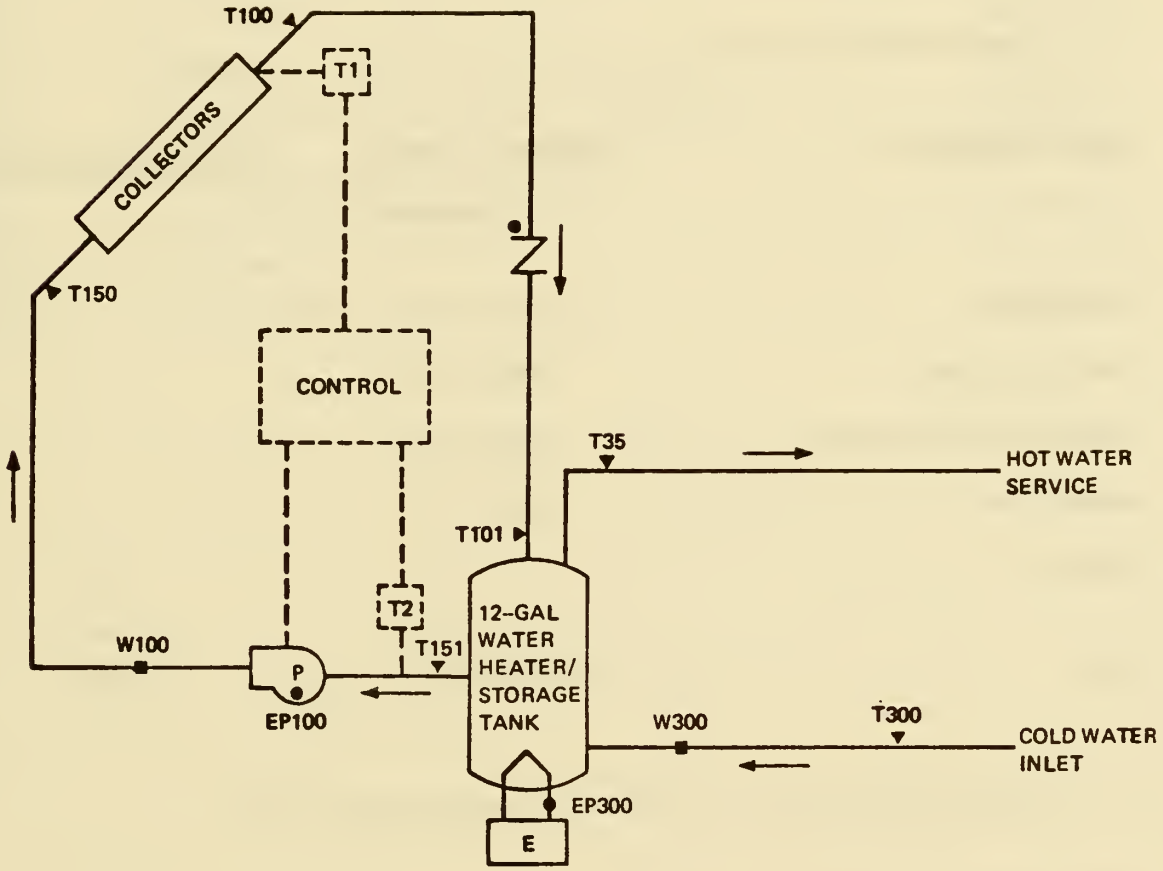


Figure V-B-1. Sensor Location Schematic

VI. COST DATA

A. General

The following cost data depicts only solar energy portion of the construction tests. Costs of test instrumentation is not encluded since it is not part of the construction effort.

B. Construction Grant Funds

Solar Sub-System	Applicants Request	Construction Grant
	Percent of total	
Collectors	$1,600 (55.2)	
Energy Storage	500 (17.4)	
Distribution & Controls	300 (10.4)	
Installation	500 (17.2)	
Others *		50
Total	$2,900 (100%)	$2,950

C. Construction Period: April 15, 1977 through May 25, 1977

* Miscellaneous hardward

SENSOR	DESCRIPTION OF MEASUREMENT	MODEL NO.
I001	Insolation, total	Eppley PSP
T001	Temperature, ambient	S53P-100
EP100	Power, control box and pump	PC5-1
W100	Flow, collector return	FloScan 300-3
T100	Temperature, return to collector	S57P-60
T150	Temperature, collector outlet	S53P-60
T101	Temperature, solar to hot water tank	S57P-60
T151	Temperature, hot water tank to collector	S53P-60
T300	Temperature, cold water inlet	S57P-100
T350	Temperature, hot water outlet	S53P-100
W300	Flow, totalizer	Hersey 430
EP300	Power, DHW heater	PC5-29

VII. APPENDIX

A. Glossary

ABSORBER PLATE - The surface in a flat plate collector that absorbs incident solar radiation and transfers the absorbed energy to a heat transfer fluid.
ABSORPTANCE - The ratio of absorbed radiation by a surface to the total incident radiation on that surface.
ABSORPTION SUBSYSTEM - The mechanical equipment that conditions indoor air by an absorption process.
ACTIVE SOLAR SYSTEM - An integrated solar energy system, consisting of collector, storage, solar energy-to-load subsystems, that can condition indoor air or preheat domestic hot water in a controlled manner.
AIR-BASED SOLAR COLLECTOR SYSTEM - A solar energy system in which air is the heat transfer fluid.
AIR CONDITIONING - The process of treating indoor air by controlling the temperature, humidity, and distribution to specified comfort settings as set by the occupants in the conditioned space.
AMBIENT AIR - A term for outdoor air, and may be brought into a building to be conditioned or circulated.
ANTI-FREEZE FREEZE PROTECTION SYSTEM - A freeze protection system that uses additives or solutions to the heat transfer medium, which depresses its freezing point sufficiently to prevent possible water freeze in the solar collectors and the exterior piping.
AUXILIARY ENERGY SUBSYSTEM - The equipment, utilizing conventional energy sources, used to supplement the output provided by a solar energy system and used to provide a full backup system when the solar system is inoperable.
BACKFLOW - The reversal of flow in a distribution system.
BACKFLOW PREVENTOR - A device or means to stop backflow.
BEAM RADIATION - Solar radiation which is not scattered and may be concentrated.
BRITISH THERMAL UNIT (Btu) - A unit of energy that is required to heat one pound of water from 59^{o} F to 60^{o} F.
BUILDING ENVELOPE - The exterior surface of a building that encloses the conditioned space.

CLIMATE - The prevailing or average weather conditions of a specific geographic region as described by temperature and other meteorological data.

COLLECTOR MANIFOLD - The piping that connects the absorber tubes in a collector plate.

COLLECTOR PLATE - A term used for an absorber plate.

COLLECTOR SUBSYSTEM - The assembly that absorbes solar radiation and transfers the absorbed thermal energy to a heat transfer fluid.

COMBINED COLLECTORS - An assembly that both collects solar radiation and stores the thermal energy in the same unit.

CONCENTRATING SOLAR COLLECTOR - A solar collector which focuses beam radiation onto an absorber in order to obtain higher energy fluxes than can normally be achieved by flat plate solar collectors.

CONCENTRATOR - A reflective surface or refracting lens used in directing insolation onto an absorber.

CONDITIONED SPACE - The space in a building where the air is conditioned by heating or cooling.

CONTROL SUBSYSTEM - The assembly of electric, pneumatic, and hydraulic actuated sensing devices used in regulating the solar energy system and the auxiliary energy subsystems.

COOLING TOWER - A heat exchanger that transfers waste heat from an absorption cooling system to ambient air.

DIFFUSE RADIATION - Solar radiation which is scattered by air molecules, dust, or other substances suspended in the air.

DRAIN-DOWN FREEZE PROTECTION SYSTEM - A freeze protection system that prevents potential water freeze-up within the collector and exterior piping by automatically draining and replacing the water with a non-freezing medium such as air, nitrogen, etc.

DUCT HEATING COIL - A liquid-to-air heat exchanger in the duct distribution system used to heat air by passing a hot fluid through a coil in the air system.

EQUIVALENT FULL LOAD COOLING HOURS - The seasonal cooling load for a building described as the total number of hours that the air conditioning system will operate under full load conditions to meet the required cooling load.

EMITTANCE - The ratio of energy radiated by a body to the energy radiated by a black body at the same temperature.

EXPANSION TANK - A tank which will permit water to expand whenever it is heated to prevent excessive pressures on the other system components.

FIXED COLLECTOR - A solar collector that is permanently oriented towards the sun and cannot track the sun nor be adjusted for seasonal variations.

FLAT PLATE COLLECTOR - A basic heat collection device used in solar heating systems, which consists of an absorber plate, with insulated bottom and sides, and covered by one or more transparent covers. There are no concentrators or focusing aids in a flat plate collector.

FOCUSING COLLECTOR - A solar collector using a parabolic mirror, fresnel lens, or other type of focusing device to concentrate solar radiation onto an absorber.

FRESNEL COLLECTOR - A concentrating solar collector which uses a fresnel lens to focus beam radiation onto an absorber.

GLAZING - The transparent cover(s) on a solar collector used to reduce the energy losses from the top of the collector.

HEAT TRANSFER FLUID - The fluid that transfers solar energy from the solar collector to the storage subsystem or to the load.

INCIDENCE ANGLE - The angle in which the insolation strikes a surface and the normal for that surface.

INSOLATION - The total amount of solar radiation on a surface in a given unit of time.

LAMINATED GLASS - A glazing consisting of multiple glass sheets bonded together by intervening layer or layers of plastic.

LANGLEY - The standard unit of insolation defined as 1 langley = 1 cal/cm^2, (1 Langley = 3.69 Btu/ft^2).

LIQUID-BASED SOLAR COLLECTOR SYSTEM - A solar energy system in which either water or an antifreeze solution is the heat transfer fluid.

LOAD - The total space conditioning or domestic water heating requirements that are supplied by both the solar energy system and the auxiliary energy subsystem.

NOCTURNAL RADIATION - The loss of thermal energy by the solar collectors to the sky at night.

NO-FLOW CONDITION - The condition obtained when the heat transfer fluid is not flowing through the collector array due to a shutdown or a malfunction.

OPAQUE - A surface that is not transparent, thus solar radiation is either reflected or absorbed.

OUTGASSING - The emission of gases by materials and components, usually during exposure to elevated temperature, or reduced pressure.

PACKAGE AIR-CONDITIONING UNIT - A factory-made assembly consisting of an indoor coil, a compressor, an outdoor coil, and other components needed for space cooling operations. This unit may also include additional components to heat the condition space.

PARABOLIC FOCUSING COLLECTOR - A concentrating collector which focuses beam radiation by a parabolic reflector.

PASSIVE SOLAR SYSTEM - An integrated solar energy system that can provide for space heating needs without the use of any other energy source other than the sun.

REFLECTANCE - The ratio of radiation reflected by a surface to the total incident radiation on the surface.

REFLECTED RADIATION - Insolation which is reflected from a surface, such as the ground, and is incident on the solar collector.

ROCK BED - A storage tank using uniform-sized rocks to store solar energy in air-based solar collector systems.

SELECTIVE SURFACE - A surface which has a high absorptance for solar radiation and a low emittance for thermal radiation.

SOLAR CONDITIONED SPACE - The area in a building that depends on solar energy to provide for a fraction of the heating and cooling needs.

SOLAR HEATING SYSTEM - An integrated assembly of collector, storage, solar energy-to-load, and control subsystems required to convert solar energy into thermal energy for space heating requirements, as well as the addition of an auxiliary backup system.

SOLAR RETROFIT - The addition of a solar energy system to an existing structure.

STORAGE SUBSYSTEM - The components used to store solar energy so that the stored energy can be used for heating, cooling, or heating water during periods of low insolation.

STRATIFICATION - The horizontal layering in a medium due to temperature differentials, commonly noticed in storage tanks filled with water.

THERMOSTAT - A temperature sensing device which controls the heating and cooling systems for space conditioning or the hot water heater.

TILT ANGLE FROM HORIZONTAL - Angle between the horizontal plane and the plane of collector.

TON OF REFRIGERATION - A unit of refrigeration which is equivalent to 12,000 Btu/hr.

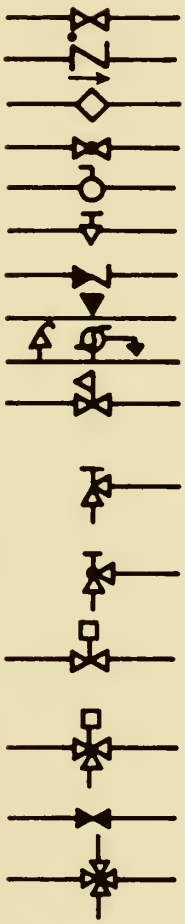
TRACKING COLLECTOR - A set of solar energy tracking collectors that automatically move in order to constantly aim towards the sun.

VAPOR BARRIER - A material which is used to reduce the transmission of water vapor.

ZONE - A portion of a conditioned space which use a common control because of their similar heating and cooling requirements.

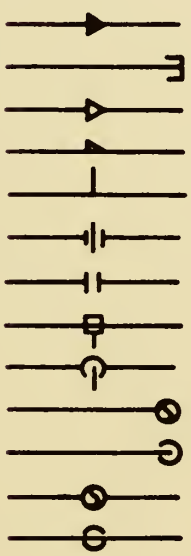
B. Legend for Solar System Schematics

VALVES



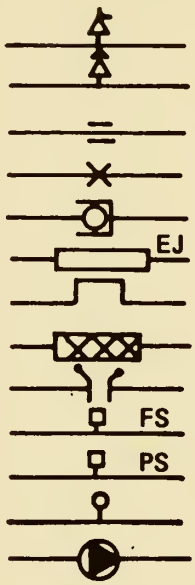
GATE VALVE
CHECK VALVE
BALANCING VALVE
GLOBE VALVE
BALL VALVE
PLUG VALVE
BACKFLOW PREVENTER
VACUUM BREAKER
RELIEF OR SAFETY
PRESSURE REDUCING
ANGLE GATE VALVE
ANGLE GLOVE VALVE
CONTROL VALVE, 2 WAY
CONTROL VALVE, 3 WAY
BUTTERFLY VALVE
4 WAY VALVE

FITTINGS



DIRECTION OF FLOW
CAP
REDUCER, CONCENTRIC
REDUCER, ECCENTRIC
TEE
UNION
FLANGED CONNECTION
CONNECTION, BOTTOM
CONNECTION, TOP
ELBOW, TURNED UP
ELBOW, TURNED DOWN
TEE, OUTLET UP
TEE, OUTLET DOWN

PIPING SPECIALITIES



AUTOMATIC AIR VENT
MANUAL AIR VENT
ALIGNMENT GUIDE
ANCHOR
BALL JOINT
EXPANSION JOINT
EXPANSION LOOP
FLEXIBLE CONNECTION
FLOWMETER FITTING
FLOW SWITCH
PRESSURE SWITCH
PRESSURE GAUGE
PUMP
PIPE SLOPE
STRAINER
STRAINER, W/BLOW OFF
TRAP
CONTROL SENSOR
INSTRUMENTATION SENSOR
THERMOMETER
THERMOMETER WELL ONLY

COLD WATER SUPPLY

AS	AIR SEPARATOR
EXP TK	EXPANSION TANK
WS	WATER SOFTENER
HED	HOSE END DRAIN